TITLE:

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CITATION:

HATA, Toshihiro ...[et al]. <Preliminary>Continuous Manufacturing of Cylindrical-LVL by using "Spiral-winding Method". Wood research : bulletin of the Wood Research Institute Kyoto University 1998, 85: 92-95

ISSUE DATE:

1998-09-30

URL:

http://hdl.handle.net/2433/53181

RIGHT:

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Preliminary

Continuous Manufacturing of Cylindrical-LVL by using "Spiral-winding Method"*[1]

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(Received May 31, 1998)

Keywords: cylindrical-LVL, Spiral-winding method, lamination pattern, bending performance

Introduction

Among the many distinctive features of wood as a structural material are its low density and high specific strength. These features are due to the special cell wall structure of wood. Consequently, many wood based products for structural applications, for example, FRP (fiber-reinforced plastics), are designed based on the structure of wood cell wall[1)], in order to achieve high specific strength and Young's modulus.

LVL (laminated veneer lumber) has become very popular due to its high yield and productivity in production process and its high reliability as a structural member.

The objective of this study is to develop new production apparatus and production technology in the continuous manufacturing of cylindrical-LVL using "Spiral-winding method", with special emphasis on the effect of lamination patterns (Fig. 1) on the bending performance.

Materials and Methods

Short pieces of rotary peeled 1 mm thickness, 45 mm wide lauan (*Shorea.* spp) veneer were sewed with thread to produce a long veneer tape which can endure tensile force during cylindrical-LVL manufacturing. The fiber direction of veneer was perpendicular to the length direction of the tape (Fig. 2-a.). Two types of resorcinol based resin adhesives mixed in selected ratios[2)] were used. The tape was coated with the adhesives and wound on a mandrel, followed by heating at about 60–70°C for 20 sec under pressure (Fig. 2-b.). The manufactured cylindrical-LVL was conditioned at about 60% RH and 20°C for 1 week.

Three-point static bending test was conducted at a cross-head speed of 5 mm/min. To

*[1] A part of this work was presented at the 47th Annual Meeting of Japan Wood Research Society in Kochi, 1997.

*[2] Laboratory Structural Function.

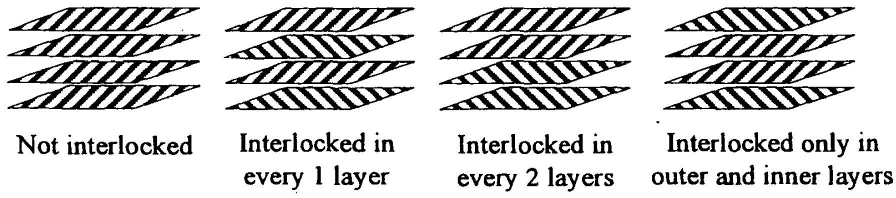

Fig. 1. Shematic diagram of lamination patterns in the case of 4-ply cylindrical-LVL. Note: the lines in the figure indicate the fiber direction of veneer.

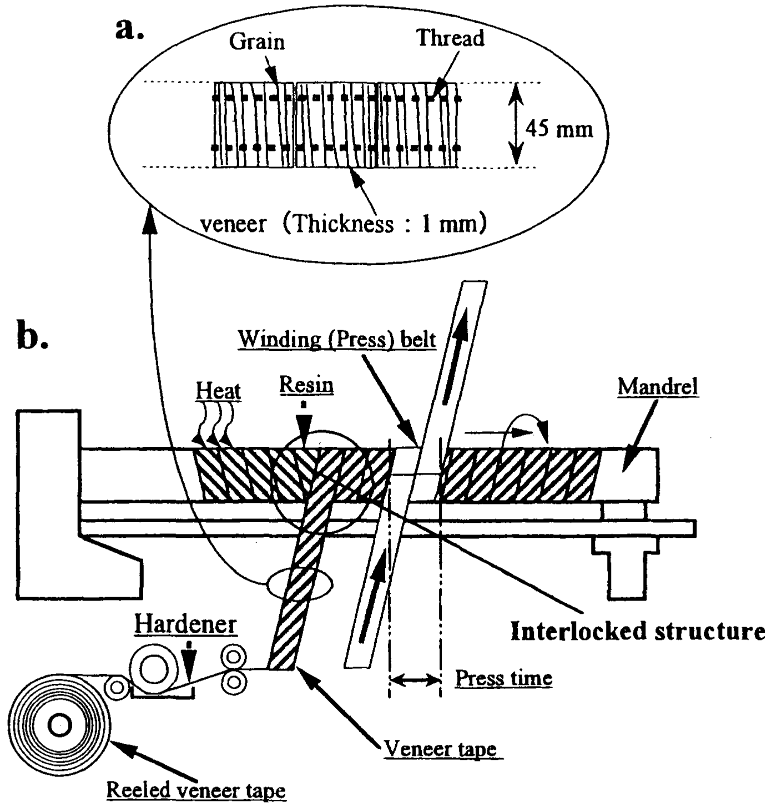

Fig. 2. Illustration of cylindrical-LVL processing.

prevent lateral deformation of cylindrical-LVL, three special metal holders were installed at the loading and supporting points[3]. Furthermore, curved metal plates were inserted between the cylindrical-LVL and the holders at the supporting points in order to prevent the cylindrical-LVL from sinking into the holders.

Results and Discussion

In the relationships between the thickness (t: $(r_2-r_1)/2$, r_1 : Inner diameter, r_2 : Outer diameter) and Young's modulus (E) of cylindrical-LVL, generally, the E decreases, as the t increases, irrespective of lamination pattern. This could be due to the size effect[4]. When the t is 0.5 mm (4-ply), cylindrical-LVL interlocked in every 1 layer has higher E compared

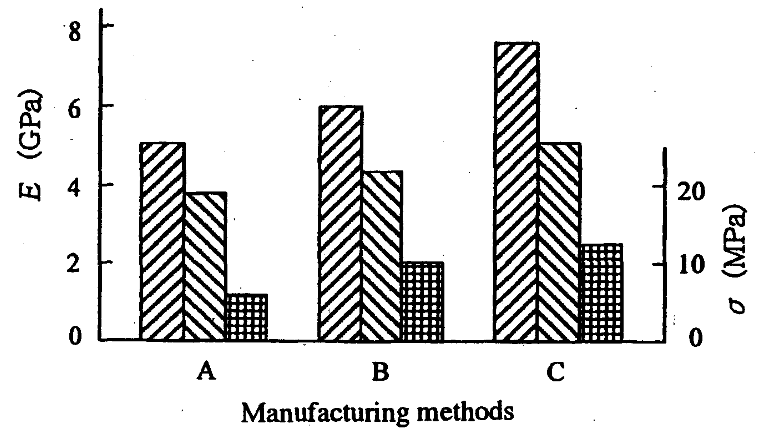

Fig. 3. Comparisons of bending perfomancer of cylindrical-LVL interlocked in every 2 lsyers. Legends : ▧: Young's modulus (Experimental value at span: $11r_2$), ▨: Young's modulus (Estimated value using experimental value at span : 5, 7, 9 and $11r_2$), ▦: Modulus of rupture Notes A : Veneer width : 45 mm, press time : 21 sec, B : Veneer width : 45 mm, press time : 42 sec, C : Veneer width : 90 mm, press time : 42 sec.

to that interlocked in every 2 layers. As the *t* increases, however, the difference between the *E* of cylindrical-LVL interlocked in every 1 layer and 2 layers decreases. At higher *t*, the increase in the ratio of interlocked structure in cylindrical-LVL interlocked in every 2 layers could have resulted in similar *E* as that interlocked in every 1 layer. Furthermore, the grain which are not parallel to each other can not contribute to high bending strength[5]. At higher *t*, lamination pattern in which veneers interlocked in every 2 or more layers is superior to that interlocked in every 1 layer in terms of the productivity during manufacturing process, and the bending performance.

In the relationships between the *t* and modulus of rupture (σ) of cylindrical-LVL, the cylindrical-LVL recorded almost constant σ irrespective of *t* and lamination pattern. When the ply number is 4, however, cylindrical-LVL was found to have low σ despite having relatively high *E*. This could be because σ was sensitive to defects in cylindrical-LVL. Especially in the case of 4-ply, the defects in cylindrical-LVL was not scattered randomly due to the low ply number.

Two major short-comings in the continuous manufacturing of cylindrical-LVL are

1) presence of many end-joint defects due to narrow veneer width,

2) low interlaminar bonding due to short press time.

A further examination was conducted on the effects of veneer width and press time on 4-ply cylindrical-LVL.

Fig. 3. shows the comparisons of bonding performances of cylindrical-LVL manufactured using various combinations of veneer width and press time. When the veneer width or press time was increased, higher *E* and σ were recorded. This could be due to a reduction in the density of end-joint defects at higher veneer width, or an improvement

in the interlaminar bonding as the press time was extended.

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